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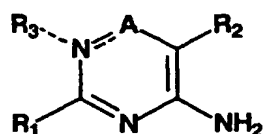
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(54) Title: ARYL SUBSTITUTED PYRIMIDINES AND THE USE THEREOF



(I)

(57) Abstract: This invention relates to a method of treating disorders responsive to the blockade of sodium ion channels using novel aryl-substituted pyrimidine compounds of Formula (I): or a pharmaceutically acceptable salt, or solvate thereof, wherein A, R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub> and R<sub>4</sub> are defined in the specification. The invention is also directed to the use of compounds of Formula I for the treatment of neuronal damage following global and focal ischemia, for the treatment or prevention of

neurodegenerative conditions such as amyotrophic lateral sclerosis (ALS), and for the treatment, prevention or amelioration of both acute or chronic pain, as antitinnitus agents, as anticonvulsants, and as antimanic depressants, as local anesthetics, as antiarrhythmics and for the treatment or prevention of diabetic neuropathy.

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## Aryl Substituted Pyrimidines And The Use Thereof

### *Background Of The Invention*

#### *Field of the Invention*

5 This invention is in the field of medicinal chemistry. In particular, the invention relates to novel aryl substituted pyrimidines, and the discovery that these compounds are blockers of sodium ( $\text{Na}^+$ ) channels.

#### *Related Art*

10 Several classes of therapeutically useful drugs, including local anesthetics such as lidocaine and bupivacaine, antiarrhythmics such as propafenone and amiodarone, and anticonvulsants such as lamotrigine, phenytoin and carbamazepine, have been shown to share a common mechanism of action by blocking or modulating  $\text{Na}^+$  channel activity (Catterall, W.A., *Trends Pharmacol. Sci.* 8:57-65 (1987)). Each of these agents is believed to act by interfering with the rapid influx of  $\text{Na}^+$  ions.

15 Recently, other  $\text{Na}^+$  channel blockers such as BW619C89 and lifarizine have been shown to be neuroprotective in animal models of global and focal ischemia and are presently in clinical trials (Graham *et al.*, *J. Pharmacol. Exp. Ther.* 269:854-859 (1994); Brown *et al.*, *British J. Pharmacol.* 115:1425-1432 (1995)).

20 The neuroprotective activity of  $\text{Na}^+$  channel blockers is due to their effectiveness in decreasing extracellular glutamate concentration during ischemia by inhibiting the release of this excitotoxic amino acid neurotransmitter. Studies have shown that unlike glutamate receptor antagonists,  $\text{Na}^+$  channel blockers prevent hypoxic damage to mammalian white matter (Stys *et al.*, *J. Neurosci.* 12:430-439 (1992)). Thus, they may  
25 offer advantages for treating certain types of strokes or neuronal trauma where damage to white matter tracts is prominent.

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Another example of clinical use of a Na<sup>+</sup> channel blocker is riluzole. This drug has been shown to prolong survival in a subset of patients with ALS (Bensimm *et al.*, *New Engl. J. Med.* 330:585-591 (1994)) and has subsequently been approved by the FDA for the treatment of ALS. In addition to the above-mentioned clinical uses, carbamazepine, lidocaine and phenytoin are occasionally used to treat neuropathic pain, such as from trigeminal neurologia, diabetic neuropathy and other forms of nerve damage (Taylor and Meldrum, *Trends Pharmacol. Sci.* 16:309-316 (1995)), and carbamazepine and lamotrigine have been used for the treatment of manic depression (Denicott *et al.*, *J. Clin. Psychiatry* 55:70-76 (1994)). Furthermore, based on a number of similarities between chronic pain and tinnitus, (Moller, A. R. *Am. J. Otol.* 18:577-585 (1997); Tonndorf, *J. Hear. Res.* 28:271-275 (1987)) it has been proposed that tinnitus should be viewed as a form of chronic pain sensation (Simpson, J. J. and Davies, E. W. *Tips.* 20:12-18 (1999)). Indeed, lignocaine and carbamazepine have been shown to be efficacious in treating tinnitus (Majumdar, B. *et al. Clin. Otolaryngol.* 8:175-180 (1983); Donaldson, I. *Laryngol. Otol.* 95:947-951 (1981)).

It has been established that there are at least five to six sites on the voltage-sensitive Na<sup>+</sup> channels which bind neurotoxins specifically (Catterall, W.A., *Science* 242:50-61 (1988)). Studies have further revealed that therapeutic antiarrhythmics, anticonvulsants and local anesthetics whose actions are mediated by Na<sup>+</sup> channels, exert their action by interacting with the intracellular side of the Na<sup>+</sup> channel and allosterically inhibiting interaction with neurotoxin receptor site 2 (Catterall, W.A., *Ann. Rev. Pharmacol. Toxicol.* 10:15-43 (1980)).

A need exist in the art for novel compounds that are potent blockers of sodium channels, and are therefore useful for treating a variety of central nervous system conditions, including pain.

### *Summary Of The Invention*

The present invention is directed to novel aryl substituted pyrimidines of Formula I.

Also, the present invention provides for pharmaceutical compositions useful for treating disorders responsive to the blockade of sodium ion channels, containing an effective amount of a compound of Formula I in a mixture with one or more pharmaceutically acceptable carriers or diluents.

Additional embodiments and advantages of the invention will be set forth in part in the description that follows, and in part will be obvious from the description, or may be learned by practice of the invention. The embodiments and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

The present invention is also related to the discovery that aryl substituted pyrimidines represented by Formula I act as blockers of sodium ( $\text{Na}^+$ ) channels.

One aspect of the present invention is directed to treating disorders responsive to the blockade of sodium channels in a mammal suffering from excess activity of said channels, by administering an effective amount of a compound of Formula I which act as blockers of sodium channels.

A further aspect of the present invention is to provide a method for treating, preventing or ameliorating neuronal loss following global and focal ischemia; treating, preventing or ameliorating pain including acute and chronic pain, and neuropathic pain; treating, preventing or ameliorating convulsion and neurodegenerative conditions; treating, preventing or ameliorating manic depression; using as local anesthetics and anti-arrhythmics, and treating tinnitus by administering a compound of Formula I to a mammal in need of such treatment or use.

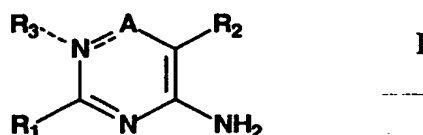
It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are

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not restrictive of the invention, as claimed.

### *Detailed Description Of The Invention*

Novel compounds of the present invention are aryl-substituted pyrimidines represented by Formula I:



or a pharmaceutically acceptable salt, or solvate thereof, wherein:

A is selected from C=O or C-R<sub>4</sub>; where:

10                   when A is C=O, the bond between N and A is a single bond  
and R<sub>3</sub> is present;

                  when A is C-R<sub>4</sub>, the bond between N and A is a double bond  
and R<sub>3</sub> is not present; and

                  R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub>  
15                   hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;

R<sub>1</sub> is selected from the group consisting of:

- (i)     phenoxyphenyl;
- (ii)   benzyloxyphenyl;
- (iii)   phenylthiophenyl;
- 20       (iv)   benzylthiophenyl;
- (v)     phenyl;
- (vi)    naphthalenyl;

                  wherein the terminal aryl ring of each of (i) to (iv), and any part of the  
ring of (v) and (vi) are optionally substituted by one or more of: halogen, C<sub>1-6</sub>  
25                   alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;  
with the proviso that when:

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(a)  $R_1$  is phenyl and A is C- $R_4$ , where  $R_4$  is hydrogen or  $C_{1-6}$  alkyl;  $R_2$  is not:

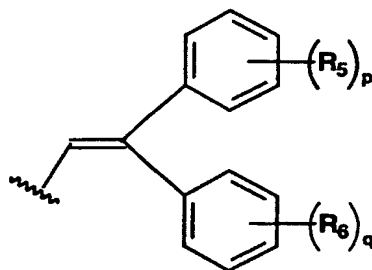
- (i) hydrogen;
- (ii)  $C_{1-3}$  alkyl;
- (iii) alkoxy substituted benzyl;
- (iv)  $C_{1-2}$  alkyloxyalkyl;
- (v)  $C_{1-2}$  hydroxyalkyl;
- (vi)  $C_{1-2}$  haloalkyl;
- (vii)  $C_{1-3}$  alkoxy; or when:

(b)  $R_1$  is phenyl and A is C=O;  $R_2$  is not hydrogen; or when:

(c)  $R_1$  is naphthalenyl and A is C- $R_4$ , where  $R_4$  is hydrogen or  $C_{1-6}$  alkyl;  $R_2$  is not:

- (i) hydrogen or
- (ii)  $C_{1-6}$  alkyl;

(vii)



wherein  $R_5$  and  $R_6$  are independently, halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and p and q are independently integers from 0 to 4;

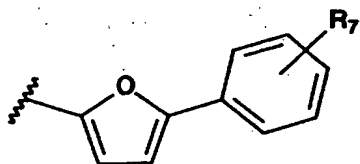
with the proviso that when:

(a) A is C- $R_4$ , where  $R_4$  is hydrogen or  $C_{1-6}$  alkyl;  $R_2$  is not:

- (i) hydrogen or
- (ii)  $C_{1-6}$  alkyl;

(viii)

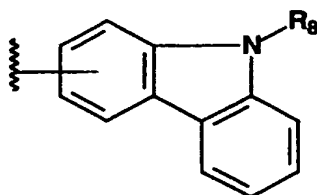
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wherein  $R_7$  is halogen  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

5

(ix)



wherein  $R_8$  is  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

$R_2$  is selected from the group consisting of:

10

(i) hydrogen;

(ii)  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

(iii) benzyl, optionally substituted with: halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

15

$R_3$  is selected from hydrogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy, or  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and is present only when A is C=O.

For  $R_1$ , the phenyl component of the phenoxyphenyl, phenylthiophenyl, benzyloxyphenyl and benzylthiophenyl moieties may be attached to the pyrimidine core at the 2-, 3- or 4-position (*i.e.*, *ortho*, *meta* or *para*, respectively) of the phenyl moiety. Preferably, the phenyl moiety is attached to the pyrimidine core through the 3- or 4-position (*i.e.*, *meta* or *para*, respectively).

20

Where  $R_1$  is phenyl, optional substituents thereon may also be positioned *ortho*, *meta* or *para*, relative to the point of attachment of the phenyl to the pyridine core. Where  $R_1$  is naphthalenyl, optional substituents

25

thereon may occupy any available position on the naphthalenyl, relative to its point of attachment on the pyrimidine core.

Preferred compounds of Formula I are those wherein A is C=O. R<sub>1</sub> is selected from phenoxyphenyl, benzyloxyphenyl or phenyl, which may be optionally substituted at the terminal aryl ring with one or more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl; R<sub>2</sub> is selected from hydrogen or benzyl optionally substituted with one or more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl, wherein the above described provisos apply; and R<sub>3</sub> is selected from hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

Particularly preferred compounds of Formula I are also those wherein A is C=O; R<sub>1</sub> is phenoxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is hydrogen or benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; and R<sub>3</sub> is selected from hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

Particularly preferred compounds of Formula I are also those wherein A is C=O; R<sub>1</sub> is phenyl, optionally substituted by halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is C<sub>1-6</sub> alkyl or benzyl, optionally substituted by halogen; and R<sub>3</sub> is selected from hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

Preferred compounds of Formula I are also those wherein A is C-R<sub>4</sub>. R<sub>1</sub> is selected from phenoxyphenyl, benzyloxyphenyl or phenyl, which may be optionally substituted at the terminal aryl ring with one or more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl; and R<sub>2</sub> is selected from hydrogen or benzyl, optionally substituted with one or more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl, wherein the above described provisos apply.

Particularly preferred compounds of Formula I, wherein A is C-R<sub>4</sub>, are those where; R<sub>1</sub> is phenoxyphenyl optionally substituted with halogen, C<sub>1-6</sub> alkyl; R<sub>2</sub> is hydrogen; and R<sub>4</sub> is selected from hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub>



alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

Especially preferred compounds of Formula I, wherein A is C-R<sub>4</sub>, are those where: R<sub>1</sub> is phenoxyphenyl optionally substituted with halogen; R<sub>2</sub> is benzyl optionally substituted with halogen; and R<sub>4</sub> is selected from hydrogen or C<sub>1-6</sub> alkyl.

For purposes of the present invention, the term "alkyl" means a linear or branched C<sub>1-10</sub> carbon chain, preferably a C<sub>1-6</sub> carbon chain. Suitable alkyl groups include, but are not limited to, methyl, ethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl, tert-butyl, 3-pentyl, hexyl and octyl groups.

The term "aryl" means a C<sub>6-14</sub> mono- or polycyclic aromatic ring system. Suitable carbocyclic aryl groups may be selected from, but are not limited to, phenyl, naphthyl, phenanthryl, anthracyl, indenyl, azulenyl, biphenyl, biphenylenyl and fluorenyl groups. Particularly preferred carbocyclic aryl groups are benzene and naphthalene.

The term "heteroaryl" means 3-7 membered monocyclic, or 7-14 membered polycyclic aromatic ring systems, independently containing one or more nitrogen, oxygen or sulfur atoms. Suitable heteroaryl groups may be selected from, but are not limited to, indole, pyridine, carbazole, imidazole, furan and the like. Preferred heteroaryl groups are pyridine, carbazol, furan and imidazole.

Non-aromatic heterocycles that are suitable for use in the present invention include, but are not limited to, pyrrolidine, piperidine and morpholine.

Exemplary preferred compounds that may be employed in this method of invention include, without limitation:

2-(4-(4-fluorophenoxy)phenyl)-6-amino-pyrimidin-4-one;

2-(4-(4-fluorophenoxy)phenyl)-6-amino-5-(2-chlorobenzyl)pyrimidin-4-one;

2-phenyl-6-amino-5-(2-chlorobenzyl)pyrimidin-4-one; and

2-(4-(4-fluorophenoxy)phenyl)-4-tert-butyl-6-aminopyrimidin-4-one;

as well as pharmaceutically acceptable salts thereof.

The invention disclosed herein is meant to encompass all pharmaceutically acceptable salts thereof of the disclosed compounds. The pharmaceutically acceptable salts include, but are not limited to, metal salts such as sodium salt, potassium salt, cesium salt and the like; alkaline earth metals such as calcium salt, magnesium salt and the like; organic amine salts such as triethylamine salt, pyridine salt, picoline salt, ethanolamine salt, triethanolamine salt, dicyclohexylamine salt, N,N'-dibenzylethylenediamine salt and the like; inorganic acid salts such as hydrochloride, hydrobromide, sulfate, phosphate and the like; organic acid salts such as formate, acetate, trifluoroacetate, maleate, tartrate and the like; sulfonates such as methanesulfonate, benzenesulfonate, p-toluenesulfonate, and the like; amino acid salts such as arginate, aspartate, glutamate and the like.

The invention disclosed herein is also meant to encompass the in vivo metabolic products of the disclosed compounds. Such products may result for example from the oxidation, reduction, hydrolysis, amidation, esterification and the like of the administered compound, primarily due to enzymatic processes. Accordingly, the invention includes compounds produced by a process comprising contacting a compound of this invention with a mammal for a period of time sufficient to yield a metabolic product thereof. Such products typically are identified by preparing a radiolabelled compound of the invention, administering it parenterally in a detectable dose to an animal such as rat, mouse, guinea pig, monkey, or to man, allowing sufficient time for metabolism to occur and isolating its conversion products from the urine, blood or other biological samples.

The invention disclosed herein is also meant to encompass the disclosed compounds being isotopically-labelled by having one or more atoms replaced by an atom having a different atomic mass or mass number. Examples of isotopes that can be incorporated into the disclosed compounds include isotopes of hydrogen, carbon, nitrogen, oxygen, phosphorous, fluorine and chlorine, such as  $^2\text{H}$ ,  $^3\text{H}$ ,  $^{13}\text{C}$ ,  $^{14}\text{C}$ ,  $^{15}\text{N}$ ,  $^{18}\text{O}$ ,  $^{17}\text{O}$ ,  $^{31}\text{P}$ ,  $^{32}\text{P}$ ,  $^{35}\text{S}$ ,  $^{18}\text{F}$ , and  $^{36}\text{Cl}$ , respectively.

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Some of the compounds disclosed herein may contain one or more asymmetric centers and may thus give rise to enantiomers, diastereomers, and other stereoisomeric forms. The present invention is also meant to encompass all such possible forms as well as their racemic and resolved forms and mixtures thereof. When the compounds described herein contain olefinic double bonds or other centers of geometric asymmetry, and unless specified otherwise, it is intended to include both E and Z geometric isomers. All tautomers are intended to be encompassed by the present invention as well.

As used herein, the term "stereoisomers" is a general term for all isomers of individual molecules that differ only in the orientation of their atoms in space. It includes enantiomers and isomers of compounds with more than one chiral center that are not mirror images of one another (diastereomers).

The term "chiral center" refers to a carbon atom to which four different groups are attached.

The term "enantiomer" or "enantiomeric" refers to a molecule that is nonsuperimposable on its mirror image and hence optically active wherein the enantiomer rotates the plane of polarized light in one direction and its mirror image rotates the plane of polarized light in the opposite direction.

The term "racemic" refers to a mixture of equal parts of enantiomers and which is optically inactive.

The term "resolution" refers to the separation or concentration or depletion of one of the two enantiomeric forms of a molecule. The phrase "enantiomeric excess" refers to a mixture wherein one enantiomer is present in a greater concentration than its mirror image molecule.

The present invention is also directed to a method for treating disorders responsive to the blockade of sodium channels in mammals suffering therefrom. Specifically, the method of the present invention utilizing the pyrimidine compounds of Formula I, without the above described provisos, may be applied to the treatment of humans or companion animals, such as dogs and cats. Particular preferred pyrimidine compounds of Formula I, for

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use in the method of the first aspect of the present invention are those as defined above, without the above described provisos.

The effectiveness of the compounds for the method of the present invention is assessed by electrophysiological assays in dissociated  
5 hippocampal neurons to determine sodium channel blocker activity. These compounds also are optionally assayed for binding to the neuronal voltage-dependent sodium channel using rat forebrain membranes and [<sup>3</sup>H]BTX-B.

Sodium channels are large transmembrane proteins that are expressed in various tissues. They are voltage sensitive channels and are responsible for  
10 the rapid increase of Na<sup>+</sup> permeability in response to depolarization associated with the action potential in many excitable cells including muscle, nerve and cardiac cells.

Another aspect of the method of the present invention is the discovery of the mechanism of action of the compounds herein described as specific Na<sup>+</sup>  
15 channel blockers. Based upon the discovery of this mechanism, these compounds are contemplated to be useful in treating or preventing neuronal loss due to focal or global ischemia, and in treating or preventing neurodegenerative disorders including ALS, anxiety, and epilepsy. They are also expected to be effective in treating, preventing or ameliorating  
20 neuropathic pain, surgical pain, chronic pain and tinnitus. The compounds are also expected to be useful as antiarrhythmics, anesthetics and antimanic depressants.

The method of the present invention is directed to the use of compounds of Formula I that are blockers of voltage-sensitive sodium  
25 channels. According to the present invention, those compounds having preferred sodium channel blocking properties exhibit an IC<sub>50</sub> of about 100 μM or less in the electrophysiological assay described herein. Preferably, the compounds of the present invention exhibit an IC<sub>50</sub> of 10 μM or less. Most preferably, the compounds of the present invention exhibit an IC<sub>50</sub> of about 1.0  
30 μM or less. The following binding and electrophysiological assays may be used to test compounds of the present invention for their Na<sup>+</sup> channel

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blocking activity.

***In vitro Binding Assay:***

The ability of compounds of the present invention to modulate either site 1 or site 2 of the Na<sup>+</sup> channel was determined following the procedures fully described in Yasushi, *J. Biol. Chem.* 261:6149-6152 (1986) and Creveling, *Mol. Pharmacol.* 23:350-358 (1983), respectively. Rat forebrain membranes are used as sources of Na<sup>+</sup> channel proteins. The binding assays are conducted in 130 μM choline chloride at 37°C for 60-minute incubation with [<sup>3</sup>H] saxitoxin and [<sup>3</sup>H] batrachotoxin as radioligands for site 1 and site 2, respectively.

***In vivo Pharmacology:***

The compounds of the present invention may be tested for *in vivo* anticonvulsant activity after i.v., p.o. or i.p. injection using a number of anticonvulsant tests in mice, including the maximum electroshock seizure test (MES). Maximum electroshock seizures are induced in male NSA mice weighing between 15-20 g and male Sprague-Dawley rats weighing between 200-225 g by application of current (50 mA, 60 pulses/sec, 0.8 msec pulse width, 1 sec duration, D.C., mice; 99 mA, 125 pulses/sec, 0.8 msec pulse width, 2 sec duration, D.C., rats) using a Ugo Basile ECT device (Model 7801). Mice are restrained by gripping the loose skin on their dorsal surface and saline-coated corneal electrodes were held lightly against the two corneae. Rats are allowed free movement on the bench top and ear-clip electrodes are used. Current is applied and animals are observed for a period of up to 30 seconds for the occurrence of a tonic hindlimb extensor response. A tonic seizure is defined as a hindlimb extension in excess of 90 degrees from the plane of the body. Results are treated in a quantal manner.

The compounds may be tested for their antinociceptive activity in the

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formalin model as described in Hunskaar, S., O. B. Fasmer, and K. Hole, J. Neurosci. Methods 14: 69-76 (1985). Male Swiss Webster NIH mice (20-30 g; Harlan, San Diego, CA) are used in all experiments. Food is withdrawn on the day of experiment. Mice are placed in Plexiglass jars for at least 1 hour to accommodate to the environment. Following the accommodation period mice are weighed and given either the compound of interest administered i.p. or p.o., or the appropriate volume of vehicle (10 % Tween-80). Fifteen minutes after the i.p. dosing, and 30 minutes after the p.o. dosing mice are injected with formalin (20  $\mu$ L of 5% formaldehyde solution in saline) into the dorsal surface of the right hind paw. Mice are transferred to the Plexiglass jars and monitored for the amount of time spent licking or biting the injected paw. Periods of licking and biting are recorded in 5 minute intervals for 1 hour after the formalin injection. All experiments are done in a blinded manner during the light cycle. The early phase of the formalin response is measured as licking / biting between 0-5 minutes, and the late phase is measured from 15-50 minutes. Differences between vehicle and drug treated groups are analyzed by one-way analysis of variance (ANOVA). A P value  $\leq 0.05$  is considered significant. Activity in blocking the acute and second phase of formalin-induced paw-licking activity is indicative that compounds are considered to be efficacious for acute and chronic pain.

The compounds may be tested for their potential for the treatment of chronic pain (antiallodynic and antihyperalgesic activities) in the Chung model of peripheral neuropathy. Male Sprague-Dawley rats weighing between 200-225 g are anesthetized with halothane (1-3 % in a mixture of 70 % air and 30 % oxygen) and their body temperature is controlled during anesthesia through use of a homeothermic blanket. A 2-cm dorsal midline incision is then made at the L5 and L6 level and the para-vertebral muscle groups retracted bilaterally. L5 and L6 spinal nerves are then be exposed, isolated, and tightly ligated with 6-0 silk suture. A sham operation is performed exposing the contralateral L5 and L6 spinal nerves as a negative control.

*Tactile Allodynia:* Rats are transferred to an elevated testing cage with

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a wire mesh floor and allowed to acclimate for five to ten minutes. A series of Semmes-Weinstein monofilaments are applied to the plantar surface of the hindpaw to determine the animal's withdrawal threshold. The first filament used possesses a buckling weight of 9.1 g (.96 log value) and is applied up to five times to see if it elicited a withdrawal response. If the animal has a withdrawal response then the next lightest filament in the series is applied up to five times to determine if it can elicit a response. This procedure is repeated with subsequent less filaments until there is no response and the lightest filament that elicits a response is recorded. If the animal does not have a withdrawal response from the initial 9.1 g filament then subsequent filaments of increased weight are applied until a filament elicits a response and this filament is then recorded. For each animal, three measurements are made at every time point to produce an average withdrawal threshold determination. Tests are performed prior to and at 1, 2, 4 and 24 hours post drug administration. Tactile allodynia and mechanical hyperalgesia tests were conducted concurrently.

*Mechanical Hyperalgesia:* Rats are transferred to an elevated testing cage with a wire mesh floor and allowed to acclimate for five to ten minutes. A slightly blunted needle is touched to the plantar surface of the hindpaw causing a dimpling of the skin without penetrating the skin. Administration of the needle to control paws typically produces a quick flinching reaction, too short to be timed with a stopwatch and arbitrarily gives a withdrawal time of 0.5 second. The operated side paw of neuropathic animals exhibits an exaggerated withdrawal response to the blunted needle. A maximum withdrawal time of ten seconds is used as a cutoff time. Withdrawal times for both paws of the animals are measured three times at each time point with a five-minute recovery period between applications. The three measures are used to generate an average withdrawal time for each time point. Tactile allodynia and mechanical hyperalgesia tests are conducted concurrently.

The compounds may be tested for their neuroprotective activity after focal and global ischemia produced in rats or gerbils according to the

procedures described in Buchan *et al.* (*Stroke*, Suppl. 148-152 (1993)) and Sheardown *et al.* (*Eur. J. Pharmacol.* 236:347-353 (1993)) and Graham *et al.* (*J. Pharmacol. Exp. Therap.* 276:1-4 (1996)).

The compounds may be tested for their neuroprotective activity after traumatic spinal cord injury according to the procedures described in Wrathall *et al.* (*Exp. Neurology* 137:119-126 (1996)) and Iwasaki *et al.* (*J. Neuro Sci.* 134:21-25 (1995)).

### ***Electrophysiological Assay:***

An electrophysiological assay was used to measure potencies of compounds of the present invention rBIIa/beta 1 sodium channels expressed in *Xenopus* oocytes.

*Preparation of cRNA encoding cloned rat brain type IIa (rBIIa) and beta 1 ( $\beta 1$ ):* cDNA clones encoding the rat brain beta 1 subunit are cloned in house using standard methods, and mRNA are prepared by standard methods. mRNA encoding rBIIa is provided by Dr. A. Golden (UC Irvine). The mRNAs are diluted and stored at -80°C in 1  $\mu$ L aliquots until injection.

*Preparation of oocytes:* Mature female *Xenopus laevis* are anaesthetized (20-40 min) using 0.15 % 3-aminobenzoic acid ethyl ester (MS-222) following established procedures (Woodward, R. M., *et al.*, *Mol. Pharmacol.* 41:89-103 (1992)).

Two to six ovarian lobes are surgically removed. Oocytes at developmental stages V-VI are dissected from the ovary, wherein the oocytes are still surrounded by enveloping ovarian tissues. Oocytes are defolliculated on the day of surgery by treatment with collagenase (0.5 mg/mL Sigma Type I, or Boehringer Mannheim Type A, for 0.5-1 hr). Treated oocytes are vortexed to dislodge epithelia, washed repeatedly and stored in Barth's medium containing 88 mM NaCl, 1 mM KCl, 0.41 mM  $\text{CaCl}_2$ , 0.33 mM  $\text{Ca}(\text{NO}_3)_2$ , 0.82 mM  $\text{MgSO}_4$ , 2.4 mM  $\text{NaHCO}_3$ , 5 mM HEPES, pH 7.4 adjusted with 0.1 mg/mL gentamycin sulphate.



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*Micro-injection of oocytes:* Defolliculated oocytes are micro-injected using a Nanoject injection system (Drummond Scientific Co., Broomall, PA). Injection pipettes are beveled to minimize clogging. Tip diameter of injection pipettes is 15-35  $\mu\text{m}$ . Oocytes are microinjected with approximately 50 nL 1:10 ratio mixtures of cRNAs for rBIIa and beta 1 respectively.

*Electrophysiology:* Membrane current responses are recorded in frog Ringer solution containing 115 mM NaCl, 2 mM KCl, 1.8 mM  $\text{CaCl}_2$ , 5 mM HEPES, pH 7.4. Electrical recordings are made using a conventional two-electrode voltage clamp (Dagan TEV-200) over periods ranging between 1-7 days following injection. The recording chamber is a simple gravity fed flow-through chamber (volume 100-500 mL depending on adjustment of aspirator). Oocytes are placed in the recording chamber, impaled with electrodes and continuously perfused (5-15  $\text{mL min}^{-1}$ ) with frog Ringer's solution. The tested compounds are applied by bath perfusion.

*Voltage protocols for evoking sodium channel currents:* The standard holding potential for whole oocyte clamp is -120 mV. Standard current-voltage relationships are elicited by 40 ms depolarizing steps starting from -60 mV to +50 mV in 10 mV increments. Peak currents are measured as the maximum negative current after depolarizing voltage steps. The voltage from maximum current response is noted and used for the next voltage protocol.

The purpose is to find compounds that are state dependent modifiers of neuronal sodium channels. Preferably, the compounds have a low affinity for the rested/closed state of the channel, but a high affinity for the inactivated state. The following voltage protocol is used to measure a compounds affinity for the inactivated state. Oocytes are held at a holding potential of -120mV. At this membrane voltage, nearly all of the channels are in the closed state. Then a 4 second depolarization is made to the voltage where the maximum current is elicited. At the end of this depolarization, nearly all the channels are in the inactivated state. A 10ms hyperpolarizing step is then made in order to remove some channels from the inactivated state. A final depolarizing test pulse is used to assay the sodium current after this prolonged depolarization

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(see analysis below). Sodium currents are measured at this test pulse before and after the application of the tested compound. Data is acquired using PCLAMP 8.0 software and analyzed with CLAMPFIT software (Axon instruments).

5           *Data analysis:* Apparent inhibition constants ( $K_i$  values) for antagonists are determined from single point inhibition data using the following equation (a generalized form of the Cheng-Prusoff equation) (Leff, P. and I. G. Dougall, *TiPS* 14:110-112 (1993)).

10                            $K_i = (FR/1-FR)*[drug]$                            Eq.2

Where FR is the fractional response and is defined as sodium current elicited from the final depolarizing test pulse prior to application of the drug divided by the sodium current measured in the presence of the drug. [drug] is the  
15           concentration of the drug used.

*Drugs:* Drugs are initially made up at concentrations of 2-10 mM in DMSO. Dilutions are then made to generate a series of DMSO stocks over the range 0.3  $\mu$ M to 10 mM - depending upon the potency of the compound. Working solutions are made by 1000-3000 fold dilution of stocks into Ringer.  
20           At these dilutions DMSO alone has little or no measurable effects on membrane current responses. DMSO stocks of drugs are stored in the dark at 4 °C. Ringer solutions of drugs are made up fresh each day of use.

Compositions within the scope of this invention include all compositions wherein the compounds of the present invention are contained in  
25           an amount that is effective to achieve its intended purpose. While individual needs vary, determination of optimal ranges of effective amounts of each component is within the skill of the art. Typically, the compounds may be administered to mammals, e.g. humans, orally at a dose of 0.0025 to 50 mg/kg, or an equivalent amount of the pharmaceutically acceptable salt  
30           thereof, per day of the body weight of the mammal being treated for epilepsy, neurodegenerative diseases, anesthetic, arrhythmia, manic depression, and

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chronic pain. For intramuscular injection, the dose is generally about one-half of the oral dose.

In the method of treatment or prevention of neuronal loss in global and focal ischemia, brain and spinal cord trauma, hypoxia, hypoglycemia, status epilepsy and surgery, the compound can be administered by intravenous injection at a dose of about 0.025 to about 10 mg/kg.

The unit oral dose may comprise from about 0.01 to about 50 mg, preferably about 0.1 to about 10 mg of the compound. The unit dose may be administered one or more times daily as one or more tablets each containing from about 0.1 to about 10, conveniently about 0.25 to 50 mg of the compound or its solvates.

In addition to administering the compound as a raw chemical, the compounds of the invention may be administered as part of a pharmaceutical preparation containing suitable pharmaceutically acceptable carriers comprising excipients and auxiliaries which facilitate processing of the compounds into preparations which can be used pharmaceutically. Preferably, the preparations, particularly those preparations which can be administered orally and which can be used for the preferred type of administration, such as tablets, dragees, and capsules, and also preparations which can be administered rectally, such as suppositories, as well as suitable solutions for administration by injection or orally, contain from about 0.01 to 99 percent, preferably from about 0.25 to 75 percent of active compound(s), together with the excipient.

Also included within the scope of the present invention are the non-toxic pharmaceutically acceptable salts of the compounds of the present invention. Acid addition salts are formed by mixing a solution of the particular pyrimidines of the present invention, with a solution of a pharmaceutically acceptable non-toxic acid such as hydrochloric acid, fumaric acid, maleic acid, succinic acid, acetic acid, citric acid, tartaric acid, carbonic acid, phosphoric acid, oxalic acid, dichloroacetic acid, and the like. Basic salts are formed by mixing a solution of the thiazolidinone compound of the

present invention with a solution of a pharmaceutically acceptable non-toxic base such as sodium hydroxide, potassium hydroxide, choline hydroxide, sodium carbonate and the like.

5 The pharmaceutical compositions of the invention may be administered to any animal that may experience the beneficial effects of the compounds of the invention. Foremost among such animals are mammals, e.g., humans, although the invention is not intended to be so limited.

10 The pharmaceutical compositions of the present invention may be administered by any means that achieve their intended purpose. For example, administration may be by parenteral, subcutaneous, intravenous, intramuscular, intraperitoneal, transdermal, or buccal routes. Alternatively, or concurrently, administration may be by the oral route. The dosage administered will be dependent upon the age, health, and weight of the recipient, kind of concurrent treatment, if any, frequency of treatment, and the  
15 nature of the effect desired.

The pharmaceutical preparations of the present invention are manufactured in a manner that is itself known, for example, by means of conventional mixing, granulating, dragee-making, dissolving, or lyophilizing processes. Thus, pharmaceutical preparations for oral use can be obtained by  
20 combining the active compounds with solid excipients, optionally grinding the resulting mixture and processing the mixture of granules, after adding suitable auxiliaries, if desired or necessary, to obtain tablets or dragee cores.

Suitable excipients are, in particular, fillers such as saccharides, for example lactose or sucrose, mannitol or sorbitol, cellulose preparations and/or  
25 calcium phosphates, for example tricalcium phosphate or calcium hydrogen phosphate, as well as binders such as starch paste, using, for example, maize starch, wheat starch, rice starch, potato starch, gelatin, tragacanth, methyl cellulose, hydroxypropylmethylcellulose, sodium carboxymethylcellulose, and/or polyvinyl pyrrolidone. If desired, disintegrating agents may be added  
30 such as the above-mentioned starches and also carboxymethyl-starch, cross-linked polyvinyl pyrrolidone, agar, or alginic acid or a salt thereof, such as

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sodium alginate. Auxiliaries are, above all, flow-regulating agents and lubricants, for example, silica, talc, stearic acid or salts thereof, such as magnesium stearate or calcium stearate, and/or polyethylene glycol. Dragee cores are provided with suitable coatings that, if desired, are resistant to gastric juices. For this purpose, concentrated saccharide solutions may be used, which may optionally contain gum arabic, talc, polyvinyl pyrrolidone, polyethylene glycol and/or titanium dioxide, lacquer solutions and suitable organic solvents or solvent mixtures. In order to produce coatings resistant to gastric juices, solutions of suitable cellulose preparations such as acetylcellulose phthalate or hydroxypropymethyl-cellulose phthalate, are used. Dye stuffs or pigments may be added to the tablets or dragee coatings, for example, for identification or in order to characterize combinations of active compound doses.

Other pharmaceutical preparations which can be used orally include push-fit capsules made of gelatin, as well as soft, sealed capsules made of gelatin and a plasticizer such as glycerol or sorbitol. The push-fit capsules can contain the active compounds in the form of granules which may be mixed with fillers such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active compounds are preferably dissolved or suspended in suitable liquids, such as fatty oils, or liquid paraffin. In addition, stabilizers may be added.

Possible pharmaceutical preparations, which can be used rectally, include, for example, suppositories, which consist of a combination of one or more of the active compounds with a suppository base. Suitable suppository bases are, for example, natural or synthetic triglycerides, or paraffin hydrocarbons. In addition, it is also possible to use gelatin rectal capsules which consist of a combination of the active compounds with a base. Possible base materials include, for example, liquid triglycerides, polyethylene glycols, or paraffin hydrocarbons.

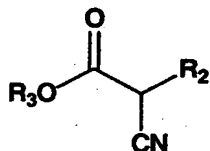
Suitable formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form, for example, water-

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soluble salts and alkaline solutions. In addition, suspensions of the active compounds as appropriate oily injection suspensions may be administered. Suitable lipophilic solvents or vehicles include fatty oils, for example, sesame oil, or synthetic fatty acid esters, for example, ethyl oleate or triglycerides or polyethylene glycol-400 (the compounds are soluble in PEG-400). Aqueous injection suspensions may contain substances which increase the viscosity of the suspension, and include, for example, sodium carboxymethyl cellulose, sorbitol, and/or dextran. Optionally, the suspension may also contain stabilizers.

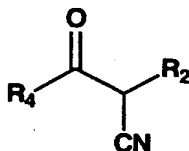
Another aspect of the present invention is directed to a method of making the novel pyrimidine compounds of Formula I, wherein the above describe provisos do not apply.

The pyrimidines of Formula I are prepared by a method comprising reacting, in a first step, a nitrile substituted aryl compound with ammonium carbonate, and in a second step, reacting the product of the first step with a nitrile compound selected from:



II

or



III

and recovering the product obtained in step two.

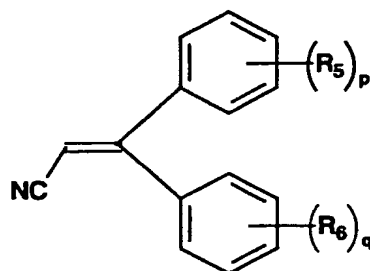
Where  $\text{R}_1$  is an optionally substituted phenoxyphenyl, the corresponding nitrile-substituted aryl compound may be prepared by reacting an optionally substituted phenol with a halophenyl nitrile compound. Where  $\text{R}_1$  is an optionally substituted benzyloxyphenyl, the corresponding nitrile-substituted aryl compound may be prepared by reacting an optionally

substituted benzylalcohol with a halophenyl nitrile compound.

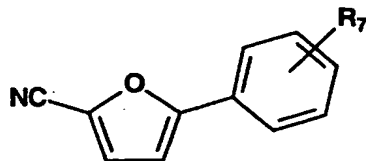
Where  $R_1$  is an optionally substituted phenylthiophenyl or optionally substituted benzylthiophenyl, the corresponding nitrile-substituted compound may be prepared by reacting an optionally substituted mercaptobenzene or an optionally substituted mercaptobenzyl compound, respectively, with a

Where  $R_1$  is an optionally substituted phenyl or optionally substituted naphthalenyl, the corresponding nitrile-substituted aryl compound is an optionally substituted benzonitrile or optionally substituted naphthalenonitrile, respectively.

Additional suitable nitrile-substituted aryl compounds for use in the present invention are:

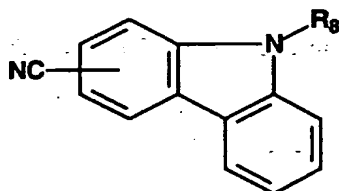


wherein  $R_5$  and  $R_6$  are independently hydrogen, halogen, optionally substituted  $C_{1-6}$  alkyl, or optionally substituted  $C_{1-6}$  alkoxy; and  $p$  and  $q$  are independently integers from 0 to 4;



wherein  $R_7$  is hydrogen, halogen or optionally substituted  $C_{1-6}$  alkyl;

and



wherein  $R_8$  is hydrogen or optionally substituted  $C_{1-6}$  alkyl.

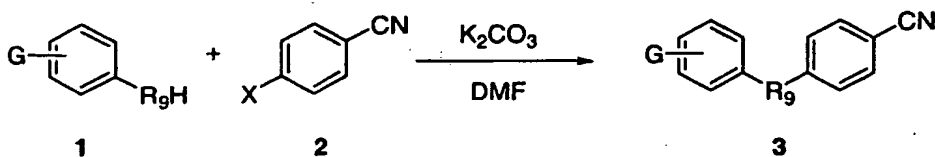
Scheme 1 exemplifies a method of making selected nitrile-substituted intermediate compounds of the invention, wherein G represents one or more optional substituents, selected from: halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl, and  $R_9$  is selected from oxygen or sulfur. The nitrile-substituted intermediate compounds of the present invention may also be made by other methods known to those of ordinary skill in the art.  $R_1$  for the selected nitrile-substituted intermediate compounds exemplified in Scheme 1 may be substituted for other previously defined  $R_1$  moieties.

Scheme 2 shows the process for making the pyrimidine compound of Formula I, according to steps 1 and 2 of the invention, wherein  $R_1$ ,  $R_2$ ,  $R_3$  and  $R_4$  have been previously defined above. Compounds 5 and 6 correspond to the compound of Formula I.

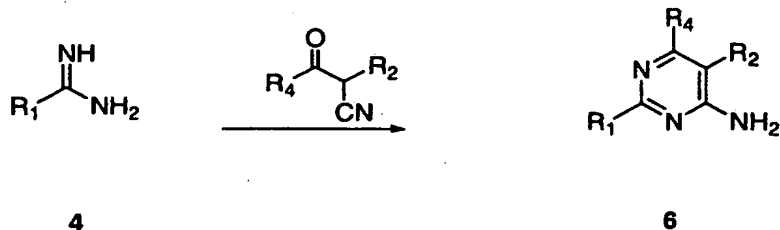
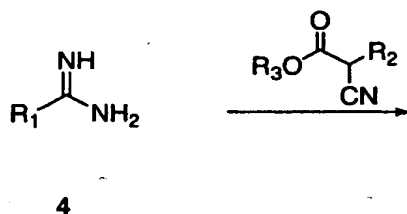
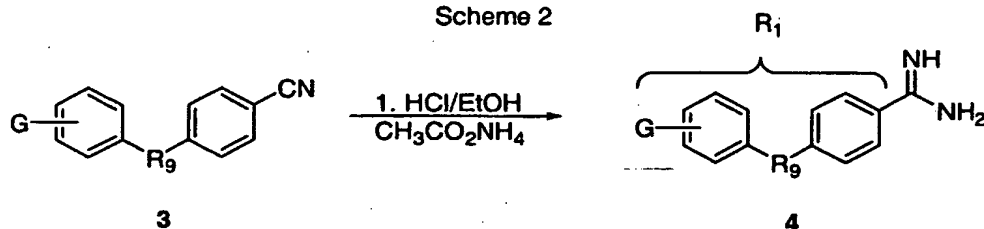


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Scheme 1

X = halogen; R<sub>9</sub> = O, S

Scheme 2



The resulting compounds are purified by flash column chromatography or silica gel chromatography.

The following examples are illustrative, but not limiting, of the method and compositions of the present invention. Other suitable modifications and adaptations of the variety of conditions and parameters normally encountered in clinical therapy and which are obvious to those skilled in the art are within

the spirit and scope of the invention.

### *Example I*

#### *Preparation of 2-(4-(4-fluorophenoxy)phenyl)-6-amino-pyrimidin-4-one (5)*

5           (a) Preparation of 4-(4-Fluorophenoxy)benzonitrile (3): A mixture of 4-fluorophenol (1) (5.1 g, 45.5 mmol), 4-fluorobenzonitrile (2) (4.58 g, 37.8 mmol) and potassium carbonate (12 g, 86.8 mmol) in DMF (150 mL) was refluxed overnight. The reaction was cooled to room temperature and partitioned between ethyl acetate and water. The aqueous layer was extracted  
10           twice with ethyl acetate. The combined organic layers were washed three times with water, dried over sodium sulfate, filtered, and evaporated under reduced pressure to give 7.5 g (93%) of crude 4-(4-fluorophenoxy)benzonitrile as solid. <sup>1</sup>H NMR (CDCl<sub>3</sub>): δ 7.60 (d, J = 9.0 Hz, 2H), 7.10-6.96 (m, 6H). Tanaka, A. et al., J. Med. Chem. 41:4408-4420 (1998).

15           (b) Synthesis of 4-(4-Fluorophenoxy)benzamidinium acetate (4): 4-(4-Fluorophenoxy)benzonitrile (4.7 g, 22.4 mmol) was dissolved in ethanol. The solution was cooled to 0 °C and HCl gas was bubbled through the solution for 20 minutes. The reaction was stoppered and stirred at room temperature overnight. The solution was evaporated under reduced pressure and the  
20           resulting solid residue was dissolved in ethanol and treated with solid ammonium acetate (6.0 g, 75.5 mol). After stirring overnight, pure amidine was isolated by filtration. Additional product was subsequently isolated from the filtrate. The filtrate was concentrated to dryness and the resulting solid was triturated 4 times with hexane and recrystallized twice from ethanol. The  
25           total weight of amidine obtained was 2.92 g (45% yield). <sup>1</sup>H NMR (DMSO-d<sub>6</sub>): δ 7.85 (d, J = 8.0 Hz, 2H), 7.31 (t, J = 8.7 Hz, 2H), 7.21-7.17 (m, 2H), 7.11 (d, J = 8.0 Hz, 2H), 1.77 (s, 3H).

(c) Synthesis of 2-(4-(4-fluorophenoxy)phenyl)-6-amino-pyrimidin-

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4-one (5): Ethanol (0.75 mL) and a sodium ethoxide solution in ethanol (0.6 mL, 21 wt.%) was added to a reaction vessel containing the amidine (4) (0.5 mmol) and 2-cyanoacetic acid (*i.e.*, the nitrile of Formula II) (1.5 mmol). The reaction was heated at 95 °C for 2 days. The reaction mixture was cooled to ambient temperature, and the solvent was evaporated. Purification of the product (5) was carried out by silica gel chromatography.

### ***Example 2***

#### ***Preparation of 2-(4-(4-fluorophenoxy)phenyl)-4-tert-butyl-6-aminopyrimidin-4-one (6)***

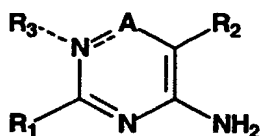
Ethanol (0.75 mL) and a sodium ethoxide solution in ethanol (0.6 mL, 21 wt.%) was added to a reaction vessel containing the amidine (4) from Example I (0.5 mmol), and cyanomethyl-tert-butyl ketone (*i.e.*, ketone of Formula III) (1.5 mmol). The reaction was heated at 95 °C for 2 days. The reaction mixture was cooled to ambient temperature, and the solvent was evaporated. Purification of the product (6) was carried out by silica gel chromatography.

### ***Example 3***

#### ***Biological Activity of Compounds of the Present Invention***

The *K<sub>i</sub>* values for sodium channel inhibition of selected compounds of the present invention were determined by the assay described above and are provided in Table 1 below.

TABLE 1

INHIBITION CONSTANTS ( $K_i$ ) FOR COMPOUNDS OF THE INVENTION

A	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	K <sub>i</sub> (μM)
C=O		H	H	-	<b>0.47</b>
C=O			H	-	30.87
C=O			H	-	49.21
C-R <sub>4</sub>		H	-		15.57

*Example 4**Tablet Preparation*

Tablets containing 25.0, 50.0, and 100.0 mg, respectively, of the compound of the invention (i.e., "active compound") are prepared as illustrated in Table 2 below.

TABLE 2

TABLET FOR DOSES CONTAINING FROM  
25-100 MG OF THE ACTIVE COMPOUND

	<i>Amount (Mg)</i>		
Active compound	25.0	50.0	100.00
Microcrystalline cellulose	37.25	100.0	200.0
Modified food corn starch	37.25	4.25	8.5
Magnesium stearate	0.50	0.75	1.5

All of the active compound, cellulose, and a portion of the corn starch are mixed and granulated to 10% corn starch paste. The resulting granulation is sieved, dried and blended with the remainder of the corn starch and the magnesium stearate. The resulting granulation is then compressed into tablets containing 25.0, 50.0, and 100.0 mg, respectively, of active ingredient per tablet. The specific amounts of each ingredient described in Table 2 are not intended to be limiting, but are rather exemplary. The amount of active ingredient maybe any amount in the range of 25-100 mg. The amounts of the remaining ingredients may thus be adjusted accordingly, as deemed necessary by those of ordinary skill in the art.

### *Example 5*

#### *Intravenous Solution Preparation*

An intravenous dosage form of the compound of the invention (*i.e.*, "active compound") is prepared as shown in Table 3 below.

TABLE 3

## INTRAVENOUS SOLUTION FORMULATION

Active compound	0.5-10.0 mg
Sodium citrate	5-50 mg
Citric acid	1-15 mg
Sodium chloride	1-8 mg
Water for injection (USP)	q.s. to 1 ml

Utilizing the above quantities, the active compound is dissolved at room temperature in a previously prepared solution of sodium chloride, citric acid, and sodium citrate in Water for Injection (USP, see page 1636 of United States Pharmacopeia/National Formulary for 1995, published by United States Pharmacopeial Convention, Inc., Rockville, Maryland (1994).

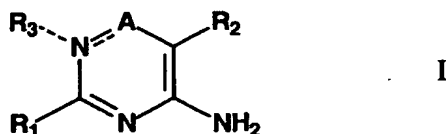
Having now fully described this invention, it will be understood by those of ordinary skill in the art that the same can be performed within a wide and equivalent range of conditions, formulations and other parameters without affecting the scope of the invention or any embodiment thereof.

Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

All patents and publications cited herein are fully incorporated by reference herein in their entirety.

***What Is Claimed Is:***

1. A compound of Formula I:



- 5 or pharmaceutically acceptable salt, or solvate thereof, wherein:

A is selected from C=O or C-R<sub>4</sub>; where:

when A is C=O, the bond between N and A is a single bond,  
and R<sub>3</sub> is present;

- 10 when A is C-R<sub>4</sub>, the bond between N and A is a double bond,  
and R<sub>3</sub> is not present; and

R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;

R<sub>1</sub> is selected from the group consisting of:

- 15 (i) phenoxyphenyl;  
(ii) benzyloxyphenyl;  
(iii) phenylthiophenyl;  
(iv) benzylthiophenyl;  
(v) phenyl;  
(vi) naphthalenyl;

- 20 wherein the terminal aryl ring of each of (i) to (iv), and any part of the  
ring of (v) and (vi) are optionally substituted by one or more of: halogen, C<sub>1-6</sub>  
alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;  
with the proviso that when:

- 25 (a) R<sub>1</sub> is phenyl and A is C-R<sub>4</sub>, where R<sub>4</sub> is hydrogen or C<sub>1-6</sub> alkyl; R<sub>2</sub>  
is not:

- (i) hydrogen;  
(ii) C<sub>1-3</sub> alkyl;

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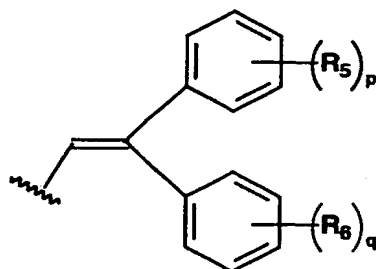
- (iii) alkoxy substituted benzyl;
- (iv) C<sub>1-2</sub> alkyloxyalkyl;
- (v) C<sub>1-2</sub> hydroxyalkyl;
- (vi) C<sub>1-2</sub> haloalkyl;
- (vii) C<sub>1-3</sub> alkoxy; or when:

(b) R<sub>1</sub> is phenyl and A is C=O; R<sub>2</sub> is not hydrogen; or when:

(c) R<sub>1</sub> is naphthalenyl and A is C-R<sub>4</sub>, where R<sub>4</sub> is hydrogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is not:

- (i) hydrogen or
- (ii) C<sub>1-6</sub> alkyl;

(vii)



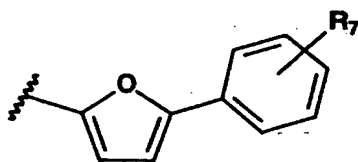
wherein R<sub>5</sub> and R<sub>6</sub> are independently, halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl; and p and q are independently integers from 0 to 4;

with the proviso that when:

(a) A is C-R<sub>4</sub>, where R<sub>4</sub> is hydrogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is not:

- (i) hydrogen or
- (ii) C<sub>1-6</sub> alkyl;

(viii)

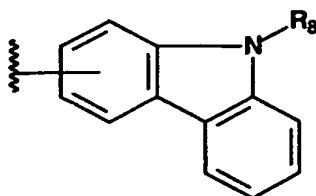




- 32 -

wherein  $R_7$  is halogen  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

(ix)



wherein  $R_8$  is  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

$R_2$  is selected from the group consisting of:

(i) hydrogen;

(ii)  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

(iii) benzyl, optionally substituted with: halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

$R_3$  is selected from hydrogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy, or  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and is present only when A is C=O.

2. The compound according to claim 1, wherein A is C=O.

3. The compound according to claim 2, wherein  $R_1$  is selected from the group consisting of:

(i) phenoxyphenyl;

(ii) benzyloxyphenyl; and

(iii) phenyl;

wherein, the terminal aryl ring of each of (i) and (ii), and any part of the ring of (iii) are optionally substituted by one or more of: halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl.

4. The compound according to claim 3, wherein R<sub>2</sub> is selected from hydrogen or benzyl, optionally substituted with halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
5. The compound according to claim 4, wherein R<sub>3</sub> is selected from hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
6. The compound according to claim 2, wherein R<sub>1</sub> is phenoxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is hydrogen; and R<sub>3</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
7. The compound according to claim 2, wherein R<sub>1</sub> is phenoxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; and R<sub>3</sub> hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
8. The compound according to claim 2, wherein R<sub>1</sub> is benzyloxyphenyl optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is hydrogen; and R<sub>3</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
9. The compound according to claim 2, wherein R<sub>1</sub> is benzyloxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; and R<sub>3</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
10. The compound according to claim 2, wherein R<sub>1</sub> is phenyl, optionally

substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; and R<sub>3</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

- 5            11.    The compound according to claim 1, wherein A is C-R<sub>4</sub>.
12.    The compound according to claim 11, wherein R<sub>1</sub> is selected from the group consisting of:
- 10            (i)    phenoxyphenyl;
- (ii)    benzyloxyphenyl; and
- (iii)   phenyl;
- wherein, the terminal aryl ring of each of (i) and (ii), and any part of the ring of (iii) are optionally substituted by one or more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
- 15
13.    The compound according to claim 12, wherein R<sub>2</sub> is selected from hydrogen or benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
- 20
14.    The compound according to claim 12, wherein R<sub>1</sub> is phenoxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is hydrogen; and R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
- 25
15.    The compound according to claim 12, wherein R<sub>1</sub> is phenoxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; and R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.
- 30

16. The compound according to claim 12, wherein R<sub>1</sub> is benzyloxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is hydrogen; and R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

17. The compound according to claim 12, wherein R<sub>1</sub> is benzyloxyphenyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; R<sub>2</sub> is benzyl, optionally substituted with halogen or C<sub>1-6</sub> alkyl; and R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl.

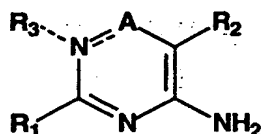
18. The compound according to claim 1, wherein said compound is selected from the group consisting of:

2-(4-(4-fluorophenoxy)phenyl)-6-amino-pyrimidin-4-one;  
2-(4-(4-fluorophenoxy)phenyl)-6-amino-5-(2-chlorobenzyl)pyrimidin-4-one;  
2-phenyl-6-amino-5-(2-chlorobenzyl)pyrimidin-4-one;  
2-(4-(4-fluorophenoxy)phenyl)-4-tert-butyl-6-aminopyrimidin-4-one; and  
pharmaceutically acceptable salts thereof.

19. A pharmaceutical composition, comprising the compound according to any one of claims 1-18, and a pharmaceutically acceptable carrier or diluent.

20. A method for treating, preventing or ameliorating a disorder responsive to the blockage of sodium channels in a mammal suffering therefrom, comprising administering to said mammal in need of such treatment, an effective amount of a compound of Formula I:

- 36 -



or pharmaceutically acceptable salt, or solvate thereof, wherein:

A is selected from C=O or C-R<sub>4</sub>; where:

when A is C=O, the bond between N and A is a single bond,  
and R<sub>3</sub> is present;

when A is C-R<sub>4</sub>, the bond between N and A is a double bond,  
and R<sub>3</sub> is not present; and

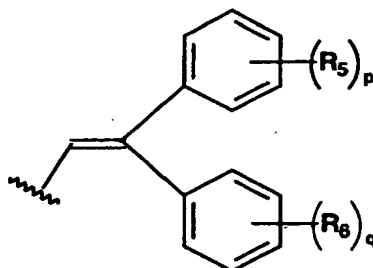
R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub>  
hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;

R<sub>1</sub> is selected from the group consisting of:

- (i) phenoxyphenyl;
- (ii) benzyloxyphenyl;
- (iii) phenylthiophenyl;
- (iv) benzylthiophenyl;
- (v) phenyl;
- (vi) naphthalenyl;

wherein the terminal aryl ring of each of (i) to (iv), and any part  
of the ring of (v) and (vi) are optionally substituted by one or  
more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub>  
hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;

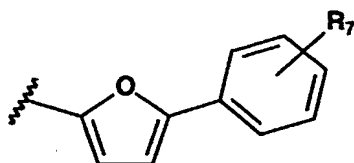
(vii)



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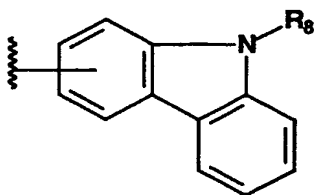
wherein  $R_5$  and  $R_6$  are independently, halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and  $p$  and  $q$  are independently integers from 0 to 4;

5 (viii)



wherein  $R_7$  is halogen  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

10 (ix)



wherein  $R_8$  is  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

$R_2$  is selected from the group consisting of:

- 15 (i) hydrogen;
- (ii)  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and
- (iii) benzyl, optionally substituted with: halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

20  $R_3$  is selected from hydrogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy, or  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and is present only when  $A$  is  $C=O$ .

21. A method for treating, preventing or ameliorating a disorder responsive to the blockage of sodium channels in a mammal suffering therefrom, comprising administering to said mammal in need of such treatment,

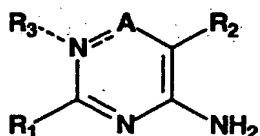
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an effective amount of a compound selected from the group consisting of:

2-(4-(4-fluorophenoxy)phenyl)-6-amino-pyrimidin-4-one;  
2-(4-(4-fluorophenoxy)phenyl)-6-amino-5-(2-chlorobenzyl)pyrimidin-4-one;  
2-phenyl-6-amino-5-(2-chlorobenzyl)pyrimidin-4-one; and  
2-(4-(4-fluorophenoxy)phenyl)-4-tert-butyl-6-aminopyrimidin-4-one; and  
pharmaceutically acceptable salts thereof.

22. The method according to any one of claims 20 or 21, wherein said disorder is selected from the group consisting of: neuronal damage; a neurodegenerative condition, acute or chronic pain, depression, and diabetic neuropathy.
23. The method according to claim 22, wherein said neuronal damage is caused by focal or global ischemia.
24. The method according to claim 22, wherein said neurodegenerative condition is amyotrophic lateral sclerosis (ALS).
25. The method according to any one of claims 20 or 21, wherein said compound functions as antitinnitus agents, anticonvulsants, antiarrhythmics, local anesthetics, or antimanic depressants.
26. The method according to any one of claims 20 or 21, wherein said mammal is a human, dog or cat.
27. A method of making the compound of Formula I:

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or pharmaceutically acceptable salt, or solvate thereof, wherein:

A is selected from C=O or C-R<sub>4</sub>; where:

when A is C=O, the bond between N and A is a single bond,  
and R<sub>3</sub> is present;

when A is C-R<sub>4</sub>, the bond between N and A is a double bond,  
and R<sub>3</sub> is not present; and

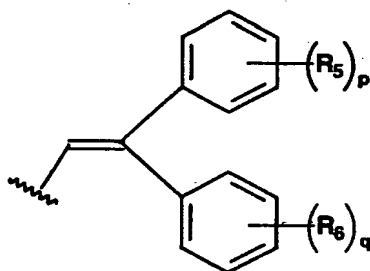
R<sub>4</sub> is hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub>  
hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;

R<sub>1</sub> is selected from the group consisting of:

- (i) phenoxyphenyl;
- (ii) benzyloxyphenyl;
- (iii) phenylthiophenyl;
- (iv) benzylthiophenyl;
- (v) phenyl;
- (vi) naphthalenyl;

wherein the terminal aryl ring of each of (i) to (iv), and any part  
of the ring of (v) and (vi) are optionally substituted by one or  
more of: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub>  
hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl;

(vii)



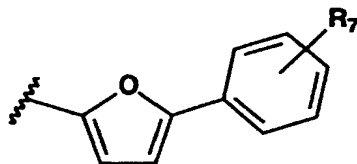


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wherein  $R_5$  and  $R_6$  are independently, halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and  $p$  and  $q$  are independently integers from 0 to 4;

5

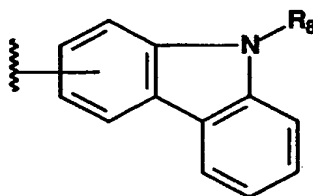
(viii)



wherein  $R_7$  is halogen  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

10

(ix)



wherein  $R_8$  is  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

$R_2$  is selected from the group consisting of:

15

(i) hydrogen;

(ii)  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

(iii) benzyl, optionally substituted with: halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl;

20

$R_3$  is selected from hydrogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy, or  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and is present only when  $A$  is  $C=O$ ;

wherein said method comprises:

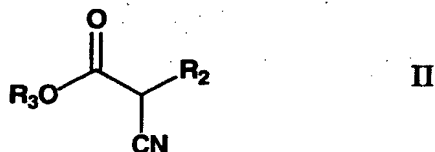
(i) reacting a nitrile-substituted aryl compound with an ammonium salt;

25

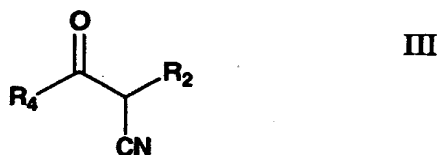
(ii) reacting the product obtained in (i) with a nitrile

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compound selected from:



or



5 (iii) recovering the product obtained from (ii).

28. The method according to claim 27, wherein the nitrile-substituted aryl compound is selected from the group consisting of:

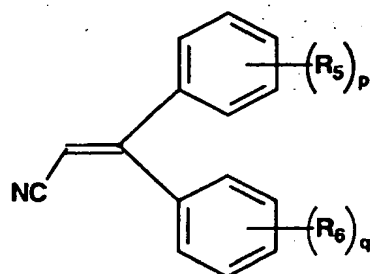
- 10 (i) phenoxybenzonitrile;  
 (ii) benzyloxybenzonitrile;  
 (iii) phenylthiobenzonitrile;  
 (iv) benzylthiobenzonitrile;  
 (v) benzonitrile;  
 (vi) naphthalenonitrile;

15 wherein, the terminal aryl ring of each of (i) to (iv), and any part of the ring of (v) and (vi), are optionally substituted by one or more of:  
 halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or  
 C<sub>1-6</sub> alkyloxyalkyl;

20

(vii)

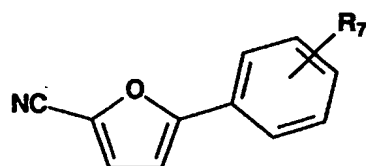
- 42 -



wherein  $R_5$  and  $R_6$  are independently, halogen,  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and  $p$  and  $q$  are independently integers from 0 to 4;

5

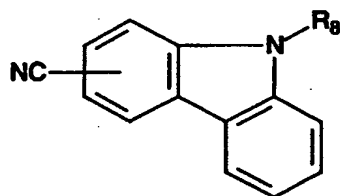
(viii)



wherein  $R_7$  is halogen  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

10

(ix)



wherein  $R_8$  is  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl.

15

29. The method according to claim 27, wherein for step (ii):

$R_2$  is selected from the group consisting of:

- (i) hydrogen;
- (ii)  $C_{1-6}$  alkyl,  $C_{1-6}$  alkoxy,  $C_{1-6}$  haloalkyl,  $C_{1-6}$  hydroxyalkyl or  $C_{1-6}$  alkyloxyalkyl; and

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(iii) benzyl, optionally substituted with: halogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, C<sub>1-6</sub> haloalkyl, C<sub>1-6</sub> hydroxyalkyl or C<sub>1-6</sub> alkyloxyalkyl; R<sub>3</sub> is selected from hydrogen, C<sub>1-6</sub> alkyl, C<sub>1-6</sub> alkoxy, or C<sub>1-6</sub> haloalkyl.

- 5        30.    The method according to claim 27, wherein the reaction solvent for step (i) comprises hydrochloric acid and an alcohol.
31.    The method according to claim 30, wherein said alcohol is selected from methanol, ethanol, or propanol.
- 10       32.    The method according to claim 31, wherein said alcohol is ethanol.